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This is an application for Letters Patent of the United States of America on an invention entitled

METHOD FOR INSTALLING BLIND THREADED INSERTS

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RELATED APPLICATIONS

The present application is related to provisional patent application serial number 60/466,410 entitled "Tool and Method for Installing Blind Threaded Inserts" filed on April 30, 2003, priority from which is hereby claimed.

FIELD OF THE INVENTION

This invention relates to an improved control method for regulating the operation of a hand tool. More specifically, it relates to a hand tool control method for the installation of blind threaded fasteners which deform under a compressive force to grip a panel.

BACKGROUND OF THE INVENTION

Blind threaded fasteners are fasteners, either internally or externally threaded, that can be first installed into a hole in a panel with access to one side of the panel only, hence the term "blind". Most of these fasteners contain three basic components: a head, an intermediate collapsible thin-walled shank, and an internally threaded region at the end. As depicted sequentially in Figures 1, 2, 3, and 4, the threaded area and a portion of the shank are first installed into the panel hole and then a compressive force is applied to the shank with a tool by pulling on the threaded region while supporting the head. This compression causes the shank to deform and buckle outwardly, creating what is known as a "bulb" on the side of the sheet opposite the head. The threaded tool member used to compress the shank is then removed, leaving the fastener permanently gripped to the panel being restrained by the head in one direction and the bulb in the other direction.

1 Presently available tools for applying the compressive load (upset force) to collapse the
2 shank can be divided into two broad categories, spin-spin tools and spin-pull tools. Both types of
3 tools utilize an anvil, also known as a nosepiece, from which a mandrel projects. Its function is to
4 support the head of the fastener while the mandrel retracts or spins to force the insert toward the
5 anvil. Spin-spin tools apply the compressive load to the shank by applying enough torque to a
6 mandrel threaded into the fastener to produce the required load. Spin-spin tools are inexpensive,
7 lightweight and simple to set up and use and are therefore generally preferred. However, because
8 the upset force they can develop is limited, they generally cannot be used to install parts having
9 thicker walls. Spin-pull tools spin the mating threaded member into position, then apply an axial
10 pulling force by retracting the mandrel. The mandrel is then removed by spinning it in the opposite
11 direction. Spin-pull tools are more complex and consequently more expensive and heavier than
12 spin-spin tools. They are also more difficult to set up and require more maintenance. In spite of
13 these disadvantages, spin-pull tools are the best available choice for thick-walled parts requiring
14 higher compressive loads to form the bulb.

15 Both types of tools require time-consuming set-up steps with some degree of trial and
16 error and a skilled operator. Spin-spin tools require mandrel length adjustment and adjustment to
17 the stall torque. Spin-pull tools require an anvil adjustment relative to the fully-extended position
18 of the mandrel and an adjustment to the stroke or pulling pressure. The set-up requirements of
19 either type of tool represent lost time and require significant operator training. To enhance their
20 operation, both types of tools often include control systems based on installing to a given torque
21 or pulling to a given distance or a given force. In either case, these limits need to be determined
22 during a set-up phase before the tool can be used.

1 Although spin-pull tools are the better choice for thick wall parts, problems persist with
2 this type of tool. Pull-to-distance tools must have their stroke set properly in order to install an
3 insert, and a certain level of skill and understanding is required to set the stroke. Also, once set-
4 up, pull-to-distance tools can only install inserts into one grip thickness. Another problem is that
5 pull-to-force tools require setting the force so that it is high enough to ensure that all inserts will
6 be installed, but not so high as to damage any inserts with the excessive force. A certain level of
7 skill and understanding is required to properly set the force. Furthermore, tools using a closed
8 hydraulic system will no longer achieve full stroke after a certain amount of hydraulic fluid has
9 leaked out of the system. If not detected immediately, this can lead to under-installed inserts.
10 Even if detected immediately, downtime will occur while hydraulic fluid is added.

11 There is therefore a need in the art to provide a spin-pull type of tool which is most
12 suitable for thick-walled applications which overcomes the disadvantages of prior art spin-pull
13 type tools for installing blind threaded fasteners.

14 SUMMARY OF THE PRESENT INVENTION

15 In order to solve the above-described problems in the art, the present tool for installing
16 blind threaded fasteners has been devised. A spin-pull tool used in combination with the control
17 system of the present invention employs the features known to spin-pull-type installation tools
18 which have means to suddenly stop the tool from applying additional force in response to a stop
19 signal, however it is the way in which the stop signal is produced which sets the present invention
20 apart from the prior art. A significant new teaching of this invention is the concept that the logic
21 necessary to properly install any bulbing-type fastener can be achieved solely by a tool control
22 system. The present invention generates a stop signal based on the relationship between the force

1 values and the motion values derived from the action of the mandrel. The improved control
2 system utilizes the shape of the force-deformation curve and not just a given pre-set force value or
3 pull distance. Hence, the control system of the present invention does not require any set-up
4 unless the mandrel is physically changed to install a different thread size.

5 It is well-known in the art that if a blind threaded insert is installed with a device capable
6 of producing a real-time plot of force-versus-deformation, a knowledgeable technician can
7 observe the shape of the developing curve and reliably determine the proper stopping point. The
8 control system of the present invention is based on an algorithm which captures the same logic
9 used by a technician operating the tool manually. The control system of the invention develops a
10 force/deformation curve as the fastener is being installed. The stop signal is generated when a
11 pre-set deformation point has been exceeded which occurs when a tangent line on the developing
12 force/deformation curve becomes negative or stops decreasing.

13 Some tools of the existing art are equipped to monitor force, deformation or both force
14 and deformation. This makes it possible to establish an acceptable range of force values or
15 deformation values, or to define a region on the force-deformation curve considered to represent
16 a proper installation. When such acceptable limits have been established it is possible for tools of
17 the existing art to provide an error message stating that the limits were not satisfied at the
18 stopping point and giving details of the discrepancy. However, for tools of the existing art, the
19 actual stopping point is always determined by either the preset torque, stroke or force of the tool.
20 The present invention, on the other hand, will always stop the installation process based on the
21 shape of the force-deformation curve. As with tools of the existing art, the tool of the present
22 invention can also be given acceptable limits and provide an error message stating that the limits

1 were not satisfied at the stopping point and giving details of the discrepancy.

2 When an error message is present, the affected unit is typically identified as possibly non-
3 conforming and segregated for further review. The present invention offers a significant
4 advantage in the case of an error or fault condition in that there is a greater probability that the
5 insert was installed properly and the unit will not require rework. This is because the control
6 system of the present invention is based on curve shape and not a given force magnitude and
7 therefore able to adapt to slight variations in grip thickness, insert dimensions or insert mechanical
8 properties. Such variations might normally occur when changing to a different manufacturing lot
9 of inserts or to a different manufacturing lot of the workpiece.

10 The present control system provides means for providing the following functions.

- 11 1) Periodically approximating the slope of the force-deformation curve.
- 12 2) Periodically calculating the force axis intercept of a straight line that is tangent to a recent
13 point on the force-deformation curve.
- 14 3) Defining a deformation setpoint.
- 15 4) Determining whether the approximate slope of the force deformation curve changes from
16 positive to negative prior to the deformation setpoint.
- 17 5) Capturing the maximum force observed prior to the defined deformation setpoint in those
18 instances when the slope changes from positive to negative prior to the deformation
19 setpoint.
- 20 6) Determining when the force axis intercept of a straight line that is tangent to a recent point
21 on the force-deformation curve becomes negative or stops decreasing after the
22 deformation setpoint has been exceeded.

1 7) Capturing the force value observed when the force intercept of a straight line that is
2 tangent to a recent point on the force-deformation curve becomes negative or stops
3 decreasing.

4 8) Generating a stop signal when a specified force value is observed.

5 9) Capturing the maximum force and maximum deformation observed during the installation
6 cycle and comparing them to a defined range of values and then calculating their deviation.

7 Therefore, it is a main object of the present invention to provide a control system for a
8 threaded blind insert installation tool which includes a logic that properly installs any bulbing type
9 fastener. It is also an object of the present invention to provide a blind threaded fastener
10 installation tool in which the set-up steps necessary with tools of the existing art are not required.
11 It is a further object of the present invention to provide a blind threaded fastener installation tool
12 which can install a variety of fasteners of the same thread size into a variety of grip dimensions
13 without the need to adjust or change the control algorithm. It is yet a further object of the present
14 invention to provide a control algorithm for a blind threaded fastener installation tool in which
15 changes in fastener or grip conditions can be detected. Other objects and advantages will become
16 apparent to those of skill in the art from the following drawings and description of the preferred
17 embodiment.

18 DESCRIPTION OF THE DRAWINGS

19 Figure 1 is a front view of the operative end of a tool which utilizes the invention and an
20 insert to be installed.

21 Figure 2 is a front view of the tool with the insert positioned on the tool in alignment with
22 an apertured panel shown in cross-section to which the insert is to be installed.

Figure 3 is a front view of the tool engaged with the insert having been installed into a panel.

Figure 4 is a front view of the tool disengaged from the insert after installation.

Figure 5 is a graph of force-versus-deformation with a series nine typical blind threaded insert installation curves plotted. The curves cover the range of grip thickness.

Figure 6 is a graph of force-versus-deformation with two typical blind threaded insert installation curves plotted; one for near minimum grip thickness and one for near maximum grip thickness.

Figure 7 is a flow chart of the algorithm used to control the tool and determine its stopping point.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The following operational sequence is an overview of the operation of the preferred embodiment of the invention and assumes a tool head mounted to the end of a robot arm. The sequence for a hand held tool manipulated by an operator is essentially the same. In the preferred embodiment shown in Figures 1-4, the pulling force is applied as many similar prior art hand tools by a hydraulic cylinder, it being understood that the control system of the invention may be applied to available tools of this type.

Referring first to Figure 1, the insert head support means 5 is adjustably attached to the body of the hydraulic cylinder 1. A threaded mandrel 6 extends from the support. The sequence of operation of the preferred embodiment begins with the mandrel in the fully extended state as shown in Figure 1. An insert 10 supported by a means not shown is in correct radial position, but is axially removed from the mandrel 6. The first action required is the rotation of the mandrel in

1 the direction required to engage the threads of the insert 10. Simultaneously the tool moves
2 axially and the mandrel thereby becomes engaged with the insert threads. The resulting position is
3 shown in Figure 2. Since the mandrel threads are now engaged with the insert threads, the insert
4 will move with the tool when the tool is moved. The next action in the sequence is to move the
5 tool to the workpiece and to insert the fastener body 17 into the hole 18 in the workpiece 19 as
6 depicted in Figure 2.

7 Referring now to Figure 3, after the insert has been installed completely so that the
8 underside of the head 20 is in intimate contact with the outer surface of the workpiece 21, the
9 pulling action is initiated. The top of the insert head 22 contacts the end surface of the head
10 support means 23 and therefore the counterbored area 24 of the insert 17 is placed in
11 compression. The compressive load causes the counterbored area to buckle outwardly creating a
12 bulb 25 which captivates the insert in the workpiece. Sensing means known in the art measures
13 force and distance at short intervals during the pulling operation. These measurements are
14 inputted into a control device that is programmed to apply a control algorithm as described below
15 and in Figures 5-7. When the control algorithm determines that the stopping point has been
16 reached a signal is immediately sent to suddenly stop applying additional force. The control
17 system will then either hold the position of the threaded member relative to the head supporting
18 member or return the threaded member to the fully extended position.

19 The next action in the installation sequence is the disengagement of the mandrel from the
20 installed insert as shown in Figure 4. This is accomplished by simultaneously rotating the
21 threaded mandrel in the direction required to disengage the threads and moving the tool axially
22 away from the insert thereby completely disengaging the tool from the installed insert 27. If not

1 already returned to its fully extended position, the tool will be moved an adequate axial distance
2 away from the installed insert and the mandrel will be returned to the fully extended position,
3 completing the installation sequence.

4 Figure 5 is a graph of force-versus-deformation that contains 9 typical curves for the
5 installation of a blind threaded insert. Beginning from left to right, the curves represent the same
6 insert installed into progressively thicker panels. As the panel thickness increases, the curve shape
7 changes. Seven of these curves exhibit an intermediate maximum point followed by a decrease in
8 force and are therefore classified as type A curves. The remaining two curves do not exhibit an
9 intermediate maximum and are therefore classified as type B curves. Of the curves shown, the
10 curve 36 is the maximum grip thickness type B curve and curve 35 is the minimum grip thickness
11 and a type A curve.

12 Therefore, two different types of force/deformation curves are observed during installation
13 depending upon the thickness of the panel into which the insert is installed. It is critical to the
14 control algorithm that, as referred to below, either a "Type A" curve (installation in a thinner
15 panel) or a "Type B" curve (installation in a thicker panel) be recognized during the installation
16 process. The "Type A" or "Type B" decision point occurs after an initial deformation setpoint
17 distance is reached, hereinafter referred to as the "offset distance." The offset distance is chosen
18 to be greater than the distance at which the relative maximum point occurs on the minimum grip
19 thickness curve 35 and less than the distance at which the increase in slope occurs on the
20 maximum grip thickness curve 36. Determining this offset distance requires first taking an
21 experimental history of the insert with panels of varying thickness as shown in Figure 5.

22 Figure 6 is a graph which depicts force-versus-deformation that contains two typical

1 curves that are developed during the installation of a blind threaded insert for two very different
2 grip thicknesses that correspond generally to minimum and maximum grip thickness curves of
3 Figure 5. The curve for an insert installed near minimum grip thickness 28 has a relative
4 maximum point 29 beyond which the load drops off as the bulb forms. When bulb formation is
5 complete (Figure 3) there is a point 30 at which there is a dramatic increase in slope that is caused
6 by the upper and lower halves of the inner wall of the counterbore making contact with each other
7 forming the bulb. The other curve for an insert installed near maximum grip thickness 37 does not
8 have a relative maximum point, but does have a point 32 representing the onset of significant
9 yielding. For this curve, the load continues to increase as the bulb is formed. When bulb
10 formation is complete there is a point 33 at which there is a dramatic increase in slope which is
11 caused by the two halves of the bulb making contact with one another.

12 Referring again to Figure 6, line 35 that is tangent to a recent point on the force
13 deformation type B curve. The control system of the invention periodically calculates this line
14 after a type B curve has been identified, that is when the force/deformation data proceeds past the
15 offset distance 34 without recording a negative slope. When the calculated tangent line registers a
16 force axis intercept less than zero, a stop signal will be generated at point 41. This occurs at
17 approximately 1,600 pounds of force. It will be noticed from the type B curve in Figure 6 that
18 this corresponds to a point on the curve when the load begins to increase rapidly.

19 Also depicted in Figure 6 is a type A curve which is identified when the periodically
20 calculated slope of the curve is less than zero and is observed before the offset distance is reached.
21 This represents an intermediate peak 29 in the curve which corresponds to an intermediate force
22 value represented by line 43. The pulling force continues until the load reaches this intermediate

1 force value multiplied by a factor which yields the ultimate stop force. A multiplier factor, say
2 1.1, is used because test results have shown that the stop force point 45 should be slightly greater
3 than the force at the intermediate peak 29, in this case approximately 1,080 pounds of force.

4 Referring now to Figure 7, a control algorithm flow chart depicts the process described
5 above. The algorithm has a branching point 37, which is based on the two curve types defined
6 above. As previously explained, the determination of curve type is based on whether the slope of
7 a line tangent to a recent point on the curve changes from a positive value to a negative value
8 before the distance exceeds the preset offset distance value. If it does, the curve is determined to
9 be type A and the right-hand branch 38 of logic is followed. If the slope does not change from a
10 positive value to a negative value before the distance exceeds the preset offset distance value the
11 curve is determined to be type B and the left-hand branch 39 of logic is followed. The two logic
12 branches merge at a later point 40 beyond which the logic is the same and requires only
13 monitoring of the force. The stop signal is generated when the force reaches a calculated value.

14 An important concept embraced by the algorithm of the invention is the significance of the
15 force axis intercept on a force deformation plot for a mechanical system loaded to yield. For a
16 given system loaded to and through the yield, the force intercept will never become negative.
17 However, if a second system is physically placed in parallel with the first system after some
18 deformation of the first system, the curve for the new, combined mechanical system will have a
19 new origin, which is negative with respect to the origin of the first system. When the bulb of a
20 blind threaded fastener is formed, the upper and lower halves of the inner wall of the counterbore
21 contact one another at the end of the process. This contact is analogous to introducing a second
22 system. For this reason, the force axis intercept going negative can be used as a reliable indicator

of the two halves of the bulb coming together and is therefore a reliable indicator that the formation of the bulb is complete.

The preferred embodiment described above can be applied equally to a hand held tool or to a robotically moved automated tool. Other embodiments are also possible and are anticipated within the scope of this invention, specifically other embodiments using different means to actuate the mandrel between the fully extended state and the stopping point. Another anticipated embodiment measures the tensile force in the mandrel or any other part connected to it, instead of measuring the compressive force in the head support member as the above embodiment.

It will be readily understood from the description of the preferred embodiment that the objects of the invention have been achieved by the preferred embodiment. Set-up steps necessary for different panel thicknesses with tools of the existing art are not required. The control algorithm installs each fastener to the optimum point for the actual fastener and grip conditions of that particular installation. Consequently, the tool can install a variety of fasteners of the same thread size into a variety of grips without the need to adjust or change the control algorithm. Also, changes in fastener or grip conditions can be detected by the location of the optimum stopping point relative to a predetermined region on the force-deformation graph.

It will be apparent to those of skill in the art from the foregoing description of the preferred embodiment that the objects and advantages of the invention have been achieved. It should be understood however that there may be other modifications and changes to the present invention that will be obvious to those of skill in the art from the foregoing description, however, the present invention should be limited only by the following claims and their legal equivalents.